



US009411039B2

(12) **United States Patent**  
**Dehlink et al.**

(10) **Patent No.:** **US 9,411,039 B2**  
(45) **Date of Patent:** **Aug. 9, 2016**

(54) **PHASED-ARRAY RECEIVER, RADAR SYSTEM AND VEHICLE**

(75) Inventors: **Bernhard Dehlink**, Munich (DE);  
**Saverio Trotta**, Munich (DE)

(73) Assignee: **Freescale Semiconductor, Inc.**, Austin, TX (US)

(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 455 days.

(21) Appl. No.: **13/977,087**

(22) PCT Filed: **Jan. 21, 2011**

(86) PCT No.: **PCT/IB2011/050278**

§ 371 (c)(1),  
(2), (4) Date: **Jun. 28, 2013**

(87) PCT Pub. No.: **WO2012/098437**

PCT Pub. Date: **Jul. 26, 2012**

(65) **Prior Publication Data**

US 2013/0293411 A1 Nov. 7, 2013

(51) **Int. Cl.**  
**G01S 7/03** (2006.01)  
**G01S 3/04** (2006.01)  
(Continued)

(52) **U.S. Cl.**  
CPC . **G01S 7/03** (2013.01); **G01S 3/043** (2013.01);  
**G01S 7/032** (2013.01); **G01S 13/931** (2013.01);  
(Continued)

(58) **Field of Classification Search**  
CPC ..... **G01S 3/043**; **G01S 7/03**; **G01S 7/032**;  
**G01S 13/34**; **G01S 13/93**; **G01S 13/931**;  
**G01S 2007/2886**; **G01S 2007/358**; **H01Q 3/26**  
USPC ..... **342/194**, **350**  
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,961,172 A \* 6/1976 Hutcheon ..... G06G 7/1928  
324/76.22  
4,160,975 A \* 7/1979 Steudel ..... G01S 3/82  
342/149

(Continued)

FOREIGN PATENT DOCUMENTS

CN 101273537 A 9/2008  
EP 2594955 A1 5/2013

(Continued)

OTHER PUBLICATIONS

Erkens Holger et al: "A Low-Cost, High Resolution, 360o Phase/Gain Shifter in SiGe BiCMOS", IEEE, 2009, pp. 1-4.

(Continued)

*Primary Examiner* — Peter Bythrow

(74) *Attorney, Agent, or Firm* — Charlene R. Jacobsen

(57) **ABSTRACT**

A phased-array receiver comprises a plurality of analog beamforming receive channels, each comprising an antenna element arranged to receive a radio frequency signal and a channel output arranged to provide an analog channel output signal. At least one of the plurality of analog beamforming receive channels comprises an in-phase downconversion mixing circuit connected to the antenna element and a local oscillator source and arranged to provide a downconverted in-phase signal to a phase rotation circuit, and a quadrature downconversion mixing circuit connected to the antenna element and the local oscillator source and arranged to provide a downconverted quadrature signal to the phase rotation circuit. The phase rotation circuit is arranged to provide to the channel output a phase-shifted analog output signal generated from the downconverted in-phase signal and the downconverted quadrature signal.

**20 Claims, 10 Drawing Sheets**

